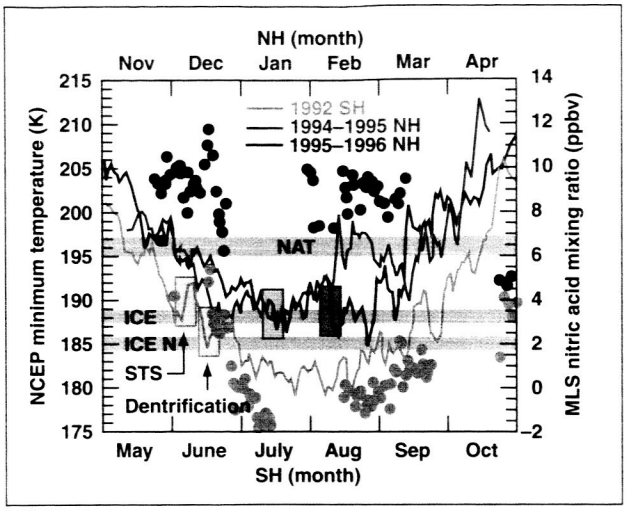

Fig. 1. Minimum temperatures are shown for a selected number of polar winters at the 50-millibars (mb) pressure level, which is near the 450 K potential temperature surface. The periods for ternary PSC formation and denitrification during the Antarctic winter of 1992 are marked in the figure as blue boxes. The NAT (nitric acid trihydrate) and ice envelopes (shaded gray) show temperatures at which nitric acid and water saturate to form nitric acid trihydrate and water ice particles, respectively. The ice nucleation envelope marks the temperature at which ice clouds can nucleate in the stratosphere. The critical temperature envelopes are calculated for nitric acid and water vapor mixing ratios of 9 to 12 parts per billion by volume and 4 to 5 parts per million by volume, respectively, based on in situ observations. Two Arctic study periods are also marked in the plot as magenta and gray boxes for the 1994–1995 and 1995–1996 winters, respectively. Symbols shown are the time series of microwave limb sounder gas-phase nitric acid averaged and binned between the 75–80° S and 75–80° N for the Antarctic and the two Arctic winters, respectively.

balloon data sets showing denitrification in the Arctic are collected either directly over or downwind of mountainous terrain (mainly over Greenland and Norwegian mountains), where lee waves could strongly affect the local reactive nitrogen (and/or water vapor) profile through small-scale cloud processing. However, the fact that satellite data show no indication of widespread denitrification in the Arctic at present suggests that the local perturbations caused by lee waves are not of global or even regional significance.

To resolve the controversy between space, in situ, and balloon observations regarding denitrification in the Arctic, a new concept was introduced at Ames that compared and contrasted "PSC lifetimes" between the two hemispheres to investigate whether PSC lifetimes could have been long enough in the past Arctic winters to have led to widespread denitrification. The concept of PSC lifetime provides new insights into how long a PSC must persist in the winter for the denitrification process to occur, and why the event currently occurs only in the Antarctic. Further, it is planned to show that future forecasted perturbations in temperature and water vapor can increase Arctic PSC lifetimes to the point where denitrification can occur during the coldest winters of the next century with important implications for Arctic ozone recovery.

Collaborators in this research include Michelle Santee (Jet Propulsion Laboratory) and Patrick Hamill (San Jose State University).

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Reduction of Trade-Cumulus Cloud Cover Due to Solar Heating by Dark Haze

Andrew Ackerman

The radiative forcings of aerosols represent a leading source of uncertainty in recent assessments of radiative forcings due to industrial activity. Although aerosol residence times are short (approximately one week or less, compared to ~50 years for carbon dioxide molecules), and they influence the radiation budget only during the day, it is estimated that by increasing reflection of sunlight, the cooling effects of aerosols may offset the radiative forcing (globally averaged). The traditional radiative forcings due to aerosols are (1) direct, by which aerosols directly scatter and absorb sunlight (cooling and heating effects, respectively), and (2) indirect, by which

aerosols increase cloud albedo, thereby reflecting more sunlight back to space (a cooling effect). Globally integrated, these forcings are estimated to range between 1 and 2 watts per square meter (W/m^2).

A primary objective of the Indian Ocean Experiment (INDOEX) was to quantify the indirect forcing of aerosols. Although a murky haze covered the Arabian Sea (during the northeast monsoon, with predominant flow off the Indian subcontinent), few clouds were found. Perhaps the presence of dark haze and the lack of clouds are not merely coincidental, but are connected. Under current evaluation is the possibility that absorption of solar energy by the dark haze dries the air sufficiently to dissipate the clouds.

The predominant cloud type expected at those latitudes is trade-cumulus, in which cloud coverage is largely determined by the coverage of stratiform "anvils" that remain after cumulus convection. The lifetime of these anvils (and therefore, their time-averaged coverage) decreases as the relative humidity of the air in which they are embedded decreases. To evaluate this hypothesis, Ames researchers ran a three-dimensional (3-D) model of cloud simulations (based on observations of trade-cumulus observed under clean conditions in the Atlantic) under clean and polluted conditions. For the indirect effect, cloud droplet concentrations were doubled from 250 to 500 per cubic centimeter ($/cm^3$), resulting in a diurnally averaged indirect radiative forcing of –12 watts per square meter (W/m^2) at the top of the atmosphere (a cooling effect), half of which is due to simply distributing cloud water over a greater surface area, and half of which is due to decreased precipitation. However, if a dark haze is also included, as observed during INDOEX in 1999 (with aerosol-induced heating rates of 2 kelvin per day (K/d) at noon), the boundary layer dries significantly during the daytime, resulting in a noticeable reduction in cloud coverage during the afternoon (see figure). The reduction in cloud coverage overwhelms the indirect cooling effect and leads to a net radiative forcing of 9 W/m^2 (a strong heating effect) for the conditions simulated. Because light-absorbing aerosols are found downwind of industrial continents, these results suggest the possibility that the global cooling effect of aerosols may be drastically overestimated.

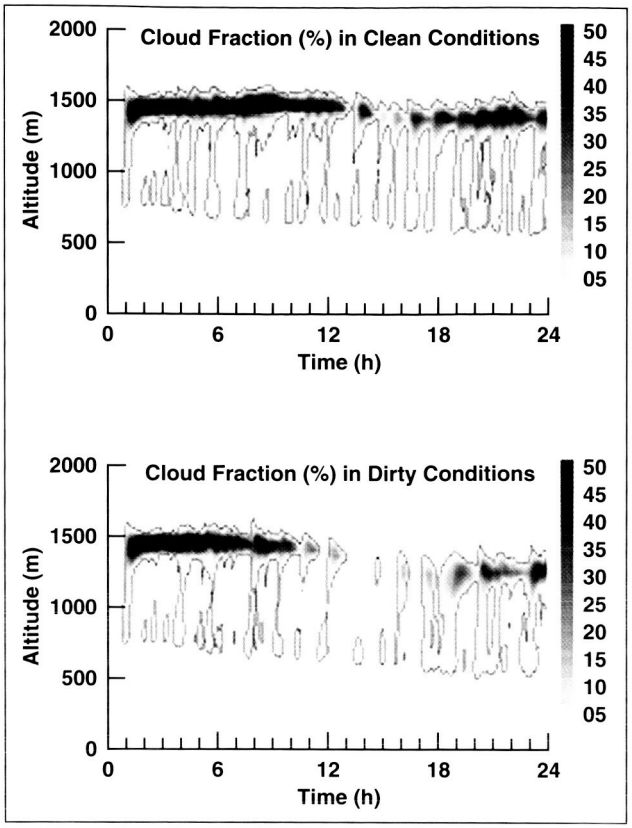

Fig. 1. This figure shows time-height contours of cloud fractional coverage (%) in 3-D model simulations of trade-cumulus in clean air (top) and in dirty air (bottom). Changes in droplet concentrations and the aerosol-induced heating in the dirty simulation are described in the text.

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